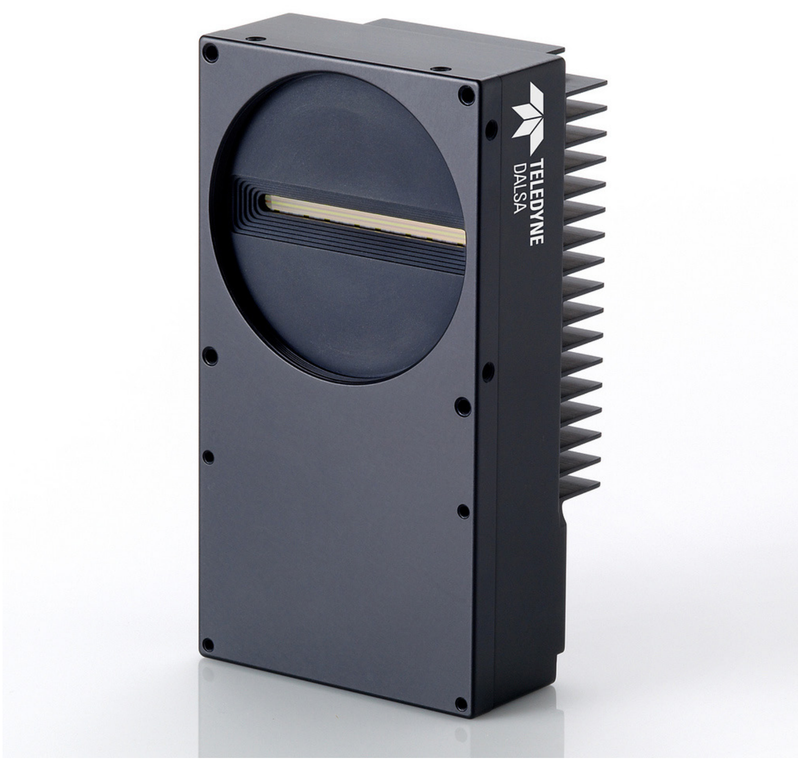
Piranha3

Camera User's Manual

16k Resolution

sensors | **cameras** | frame grabbers | processors | software | vision solutions



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Piranha3 16k CMOS Line Scan Camera

1.1 Camera Highlights

Features

- 16, 384 pixels, 3.5 µm x 3.5 µm pixel pitch, 100% fill factor.
- 1,179 MPix / s (HSLink) and 655 MPix/ s (Camera Link) data rates.
- 72 kHz (P3-S0-16k40 HSLink) and 40 kHz (P3-S0-16k20 HSLink and P3-80-16K40 Camera Link) line rates.

Programmability

- HSLink and CameraLink control interface, 115200 fixed signal baud rate. (Future models upgraded to GenICam).
- Programmable gain, line rate, trigger mode, test pattern output, and camera diagnostics.
- Flat-field correction—minimizes lens vignetting, non-uniform lighting, and sensor FPN and PRNU.

Description

The Piranha3 16k CMOS line scan camera raises resolution and speed to a new level. The 16k pixel resolution and up to a speedy 72 kHz line rate is ideally suited for the inspection of large-area flat-panel displays and printed circuit boards.

Applications

- Flat-panel display inspection
- Printed circuit board inspection
- Parcel sorting
- High performance document scanning
- High throughput applications

Models

Table 1: Piranha P3-S0, P3-80 Camera Models Overview

Model Number	Description
P3-S0-16K40-00-R	16k resolution, 72 kHz line rate, 1179 Mpix/ s throughput, HSLink interface.
P3-S0-16K20-00-R	16k resolution, 40 kHz line rate, 655 Mpix/ s throughput, HSLink interface.
P3-80-16K40-00-R	16k resolution, 40 kHz line rate, 655 Mpix/ s throughput, Camera Link interface.

1.2 Camera Performance Specifications

Table 2: Camera Performance Specifications

Feature / Specification	
Imager Format	CMOS line scan
Resolution	16, 384 pixels
Pixel Fill Factor	100 %
Pixel Size	3.5 µm x 3.5 µm
Antiblooming	100 x

Optical Interface	
Back Focal Distance	12 mm
Sensor Alignment (aligned to sides of camera)	
Flatness	25 µm
Θ y (parallelism)	0.08° or 81 µm
x	± 80 µm
y	± 80 µm
z	± 250 µm
Θ z	± 0.1°
Lens Mount	M72 x 0.75

Mechanical Interface	
Camera Size	80 mm (W) x 150 mm (L) x 77 mm (D) / 54 mm without optional heatsink
Mass	< 800 g
Connectors	
Power	Hirose 12 V to 15 V DC
Control / Data	HSLink, CameraLink
Mounting Holes	M4x0.7, 7.0 depth

Electrical Interface	
Input Voltage	12 V to 15 V DC (at camera)
Power Dissipation	20 W (HSLink model) 18 W (Camera Link model)
Operating Temperature[1]	0 °C to 50 °C
Bit Depth	8 bit, 10 bit, 12 bit (HSLink models) 8 bit and 10 bit (Camera Link model)
Output Data Configuration	HSLink, CameraLink

Operating Ranges	P3-S0-16k40	P3-S0-16k20 and P3-80-16k40
Minimum Line Rate	1 Hz	1 Hz
Maximum Line Rate	72 KHz	40 KHz
Throughput	1,179 Mpix/ s	655 Mpix/ s
Gain	0 dB to +20 dB	0 dB to +20 dB

Test conditions unless otherwise noted:

- Line Rate: 10 kHz.
- Nominal Gain setting 0 dB.
- Light Source: Broadband Quartz Halogen, 3250 k, with 700 nm IR cutoff filter installed.
- All specifications are measured at 25 °C (front plate measurement).

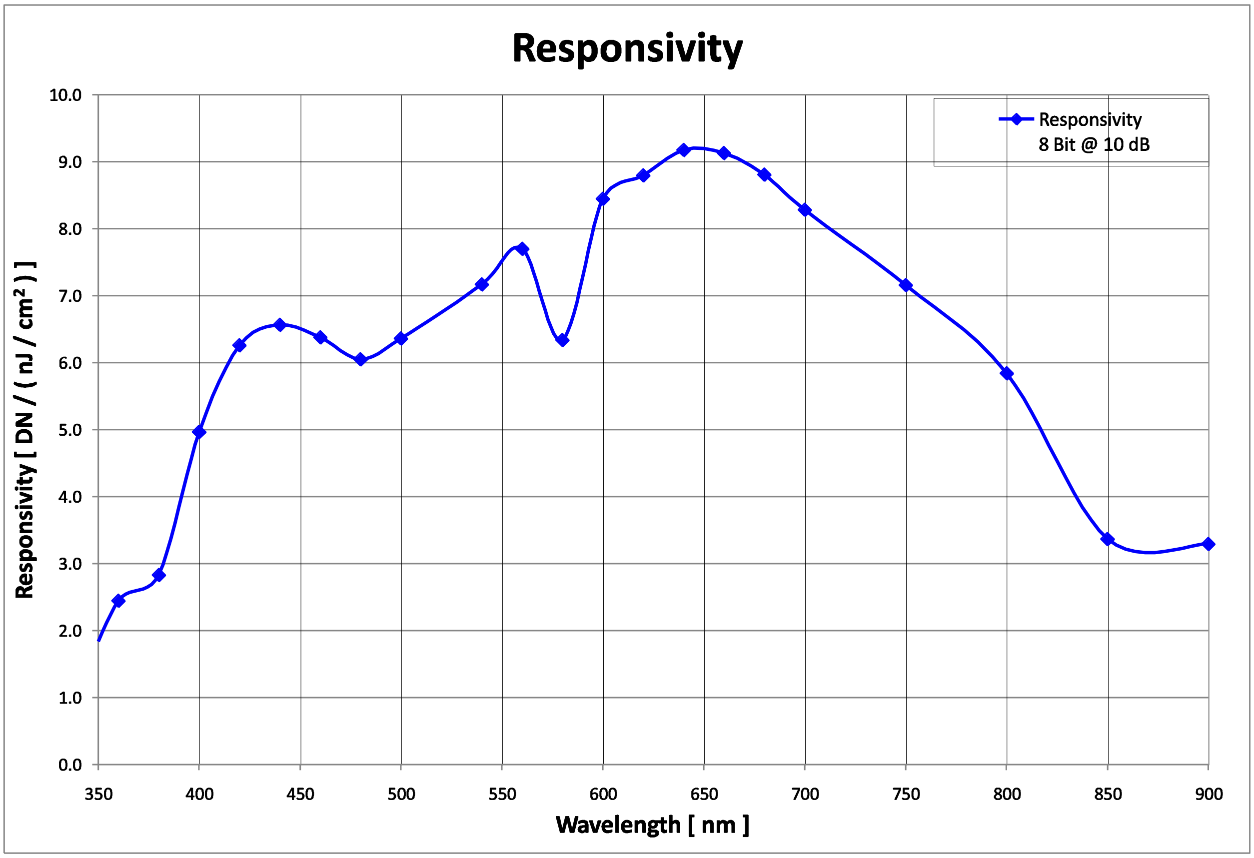
1. Measured at the front plate. It is the user's responsibility to insure that the operating temperature does not exceed this range.

Performance*	Gain 0 dB			Gain +10 dB			Gain +20 dB		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Dynamic Range	500			160			50		
Random Noise DN rms			0.5			1.5			4.8
SEE nJ/ cm^2		0.8			0.26			0.08	
NEE pJ/ cm^2		1.6			1.6			1.6	
Corrected Broadband Responsivity (DN/ nJ/ cm^2)		2.8			8.8			28	
FPN DN p-p with correction			2						
FPN DN p-p w/ o correction			4			13			41
PRNU DN p-p with correction			2						
PRNU % w/ o correction			25			25			25
Saturation Output Amplitude DN	255								

*Measused in 8-bit configuration.

1.3 Responsivity

Responsivity vs. Wavelength: Measured from the camera.



2

Camera Hardware Interface

2.1 Installation Overview

(This installation overview assumes you have not installed any system components yet.)

When installing your camera, you should take these steps:

1. Power down all equipment.
2. Follow the manufacturer's instructions to install the framegrabber (if applicable). Be sure to observe all static precautions.
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies. Ensure that all the correct voltages are present at the camera end of the power cable. Power supplies must meet the requirements defined in the Power Connector section below.
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or the camera may be damaged.
6. Connect data and power cables.
7. After connecting cables, apply power to the camera.
8. Use the verify voltage (vv) command to verify that the camera is receiving a voltage of 12 to 15 DC. If the camera is receiving less than the recommended voltage, then you may have to upgrade and/ or shorten the power cable you are using.
8. Check the diagnostic LED. See LED Status Indicator for an LED description.

You must also set up the other components of your system, including light sources, camera mounts*, host computers, optics, encoders, and so on.

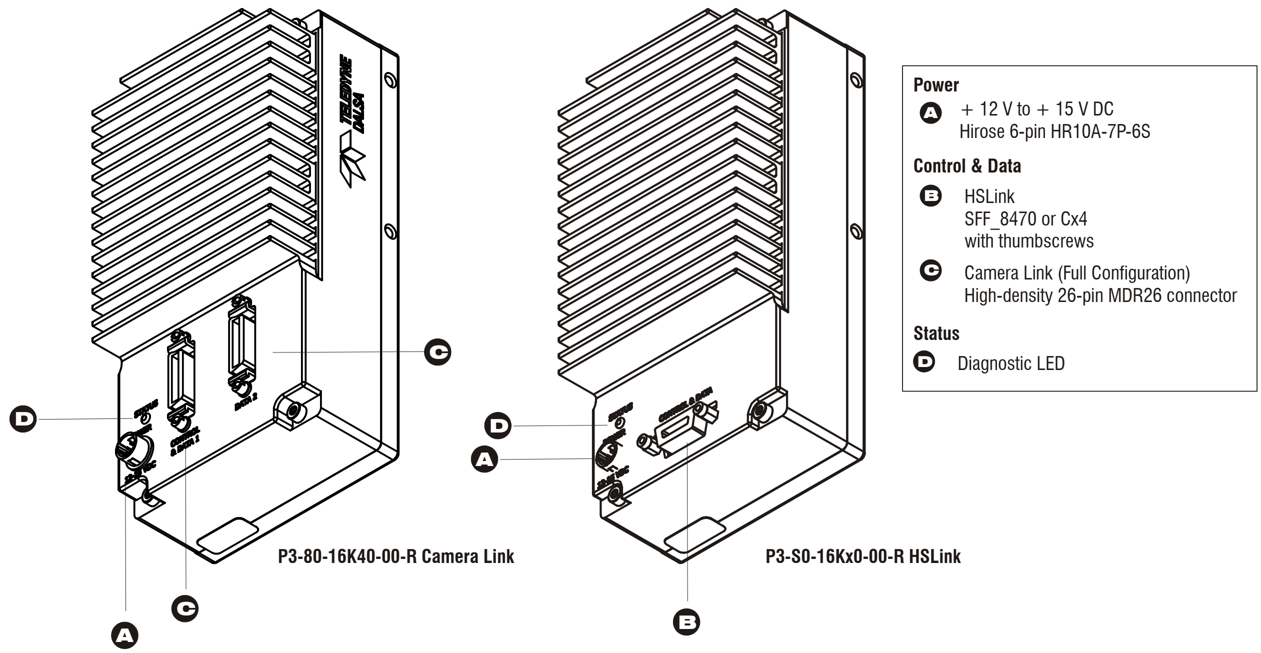
*Please see 4.2 High Temperature and Mounting for more information on camera mounting and heat dispertion.

2.2 Input/Output Connectors and LED

The camera uses:

- A diagnostic LED for monitoring the camera. See LED Status Indicator in section LED Status Indicator for details.
- A 6-pin Hirose connector for power. Refer to the Power Connector section below for details.
- The HSLink modles use a SFF_8470 / CX4 (with thumbscrews) for control, data and serial communication.
- The Camera Link model uses 2 high-density 26-pin MDR26 connectors for control, data and serial communication.

Figure 1: Input and Output Connectors



WARNING: It is extremely important that you supply the appropriate voltages to your camera. Incorrect voltages will damage the camera.

LED Status Indicator

The camera is equipped with an LED used to display the operational status of the camera. The table below summarizes the operating states of the camera and the corresponding LED states.

When more than one condition is active, the LED indicates the condition with the highest priority. Error and warning states are accompanied by corresponding messages further describing the current camera status.

Table 3: HSLink Diagnostic LED

Color of Status LED	Meaning
Green solid	Camera is operational and functioning correctly.
Green blinking, fast	FG only - LVAL present but not grabbing (20 second time out)
Green blinking, slow	Waiting for LVAL/ Trigger Line Scan – 5 second timeout
Orange (red and green on together) solid	Running on FPGA/ micro backup

Color of Status LED	Meaning
Orange blinking, slow	Loss of functionality
Orange one pulse of 0.2 sec	Random Error with HSLINK
Red blinking, fast	Fatal Error- Loss of FPGA code and or micro code
Red blinking, medium	Fatal Error- Loss of other hardware which prevents operation
Red blinking, slow	Over temperature (HSLINK CMD channel still functional)
Red / Green alternating, fast	Link Up, but idle not locked (held in Farend reset)
Red / Green alternating, medium	Incompatilbe HSLINK configuration
Red / Green alternating, slow	Looking for Link

Power Connectors

2.2.2 Power Connector

Figure 2: Hirose 6-pin Circular Male—Power Connector

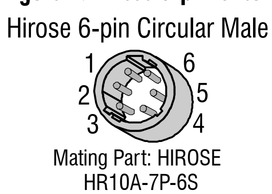


Table 4: Hirose Pin Description

Pin	Description	Pin	Description
1	Min +12 to Max +15V	4	GND
2	Min +12 to Max +15V	5	GND
3	Min +12 to Max +15V	6	GND

The camera requires a single voltage input (+12 V to +15 V DC). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear supplies provide optimum performance.

WARNING: When setting up the camera's power supplies follow these guidelines:

- Apply the appropriate, reliable voltages
- Protect the camera with a **slow-blow fuse** between power supply and camera (2x nominal current).
- Do not use the shield on a multi-conductor cable for ground.
- Keep leads as short as possible to reduce voltage drop.
- Use high-quality **linear** supplies to minimize noise.
- Use an isolated type power supply to prevent LVDS common mode range violation.
- A stable supply of power must be maintained during code upgrades. Camera will fail if power is lost or unstable while updating code. The user can not recover from this failure and the camera will have to be returned to Teledyne DALSA for repair.

Note: Camera performance specifications are not guaranteed if your power supply does not meet these requirements.

Data Connectors

HSLink Pinout

SFF_8470 (or CX4) with thumbscrews			
Signal	**Camera**	**Frame Grabber Input**	**Frame Grabber Signal**
DataTx 2+	S16	S1	DataRx 2+
DataTx 2-	S15	S2	DataRx 2-
DataTx 1+	S14	S3	DataRx 1+
DataTx 1-	S13	S4	DataRx 1-
DataTx 0+	S12	S5	DataRx 0+
DataTx 0-	S11	S6	DataRx 0-
Cmd_T+	S10	S7	Cmd R+
Cmd_T-	S9	S8	Cmd R-
Cmd_R-	S8	S9	Cmd_T-
Cmd_R+	S7	S10	Cmd_T+
DataTx 5-	S6	S11	DataRx 5-
DataTx 5+	S5	S12	DataRx 5+
DataTx 4-	S4	S13	DataRx 4-
DataTx 4+	S3	S14	DataRx 4+
DataTx 3-	S2	S15	DataRx 3-
DataTx 3+	S1	S16	DataRx 3+
Signal Ground	G1- G9	G1- G9	Signal Ground
Signal Ground	H1-H2	H1-H2	Signal Ground

Input Signals

The camera accepts control inputs through the HSLink connector.

Table 5: Camera Control Configuration

Signal	Configuration
CC1	EXSYNC

The camera ships in internal sync, internal programmed integration.

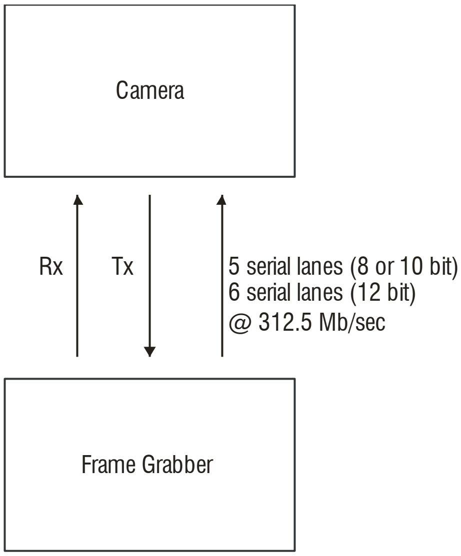
EXSYNC (Triggers Frame Readout)

Frame rate can be set internally using the serial interface. The external control signal EXSYNC is optional and enabled through the serial interface. This camera uses the **falling edge of EXSYNC** to trigger pixel readout. See section Exposure Mode and Line Rate for details on how to set frame times, exposure times, and camera modes.

An Important Note: Do not stop imaging with the ESYNC signal high. If the EXSYNC signal is high when imaging stops an imaging artifact will remain on the next line.

Output Signals

Note that LVAL and FVAL are embedded in data lanes. For additional information refer to the HSLink supplementary information below.



Frame Grabbers

The cameras (HSLink) are compatible with the Xcelera-HS PX8 framegrabber.

HSLINK and Frame Grabber Supplementary Information

Teledyne DALSA designed and pioneered the HSLink as a comprehensive camera-frame grabber communication standard targeted at machine vision industry use. The HSLink 12k and frame grabber product are based on the fundamental capabilities of this new interface.

We are working with industry partners to improve and to broaden the interface's appeal for the machine vision industry and as a result expect that the original specification will change and be improved. Products delivered during this draft specification phase will be field upgradeable so that customers can gain the benefit from an industry approved interface. The table below summarizes the major functions supported.

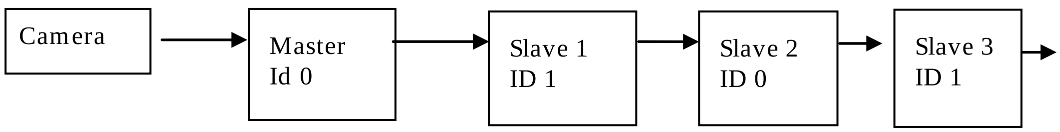
HSLINK Function	Production	Comment
Cable Disconnect Recovery	Yes	Cameras will only properly lock to frame grabber when the camera is turned on before or after starting the data acquisition program. Turn off the camera when exiting a program that uses the Frame grabber.
Data Forwarding	Yes	Customer must identify the Master/ Slave Frame grabber during the system configuration step. There is no Master/ Slave communication channel support.
Communication Between FG	No	This is the GMII command channel and will enable auto enumeration of slaves and data resend requests from the slaves.
Video Data Resend	No	Master/ Slave command channel used for error communication from slave is not available at this time. Can be field upgraded.
LED functions	Yes	
GeniCam	No	Use the ASCII serial command set.
Trigger Control	Yes	
12 bit mode	Yes	Data will be packed on the Link. This will exceed the PCIx 8 Gen 1 bandwidth.
Missed Trigger Flag	Yes	
DATA CRC Error Flag	Yes	CRC error counters available
Header Error Flag	Yes	Header error counter available
8b/ 10B Error counter	Yes	Enables BER calculation
Test Patterns	Yes	Good for system debug
Data Lost Flag	No	Indicates missing rows of information
Camera Data buffer overflow	No	
Idle Lock Lost	No	
Far end Reset	No	
Cmd Packet Failure	No	
Master/ Slave HSLINK reset	No	

Camera to Master Frame grabber Power On Discovery Notes

The camera and frame grabber will correctly discover each other if either the camera or the frame grabber are turned on or off, regardless of order.

Master to Slave Power On Discovery Notes

Please Note: The communication channel between master and slave frame grabbers is not functional at this time and therefore must be configured manually, as shown below:



The power on sequence for the cameras to guarantee functionality is:

1. Camera/ Master
2. Slave 1
3. Slave 2
4. Slave 3
5. Slave 4
6. Slave 5

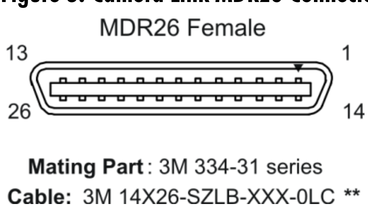
The slave should only be turned on once an image is acquired by the preceding slave.

2.2.3 Camera Link Data Connector

Camera Link information available from our Web site

The Camera Link Implementation Road Map, available from the Teledyne DALSA Web site, http:/ www.teledynedalsa.com/ mv/ knowledge/ appnotes.aspx, contains detailed information on implementing Camera Link, including configuration and signal information.

Figure 3: Camera Link MDR26 Connector



**3M part 14X26-SZLB-XXX-0LC is a complete cable assembly, including connectors.
Unused pairs should be terminated in 100 ohms at both ends of the cable.

A note concerning the length of the Camera Link cables

The length of the cables over which data can be transmitted without loss depends on the data rate and on the quality of the cables.

The camera is tested using a recognized brand of cable with a length of 5 meters. Data transmission is not guaranteed if you are using a cable greater than 5 meters in length.

Camera Link Configuration

The Camera Link interface is implemented as a Medium or Full Configuration in the Piranha 3 cameras.

Table 6: Camera Link Hardware Configuration Summary

Configuration	8 Bit Ports Supported	Serializer Bit Width	Number of Chips	Number of MDR26 Connectors
Full	A, B, C, D, E, F, G, H	28	3	2

Table 7: Camera Link Connector Pinout

Full Configuration			
Camera Connector	**Right Angle Frame Grabber**	**Channel Link Signal**	**Cable Name**
1	1	inner shield	Inner Shield
14	14	inner shield	Inner Shield
2	25	Y0-	PAIR1-
15	12	Y0+	PAIR1+
3	24	Y1-	PAIR2-
16	11	Y1+	PAIR2+
4	23	Y2-	PAIR3-
17	10	Y2+	PAIR3+
5	22	Yclk-	PAIR4-
18	9	Yclk+	PAIR4+
6	21	Y3-	PAIR5-
19	8	Y3+	PAIR5+
7	20	100 ohm	PAIR6+
20	7	terminated	PAIR6-
8	19	Z0-	PAIR7-
21	6	Z0+	PAIR7+
9	18	Z1-	PAIR8-
22	5	Z1+	PAIR8+
10	17	Z2-	PAIR9+
23	4	Z2+	PAIR9-
11	16	Zclk-	PAIR10-
24	3	Zclk+	PAIR10+
12	15	Z3-	PAIR11+
25	2	Z3+	PAIR11-
13	13	inner shield	Inner Shield
26	26	inner shield	Inner Shield

Table 8: Camera Control Configuration

Signal	Configuration
CC1	EXSYNC
CC2	PRIN
CC3	Spare
CC4	Spare

Table 9: Camera Link Pixel Readout Configurations: Full Camera Link Configuration and Bit Depth 8

Camera Link Mode Configuration (Controlled by clm command): Full and Bit Depth 8		
Command	**Camera Link Taps**	**Pixel Rate Configuration (Controlled by sot command)**
sdw 8	8 Camera Link taps where: 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel	**sot 320** = NA

Table 10: Camera Link Pixel Readout Configurations: Full Camera Link Configuration and Bit Depth 10

Camera Link Mode Configuration (Controlled by clm command): Full and Bit Depth 10		
Command	**Camera Link Taps**	**Pixel Rate Configuration (Controlled by sot command)**
sdw 10	8 Camera Link taps where: 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel 1 = Every 4th Odd Pixel 2 = Every 4th Even Pixel 3 = Every 4th Odd Pixel 4 = Every 4th Even Pixel	**sot 320** = NA

Input Signals, Camera Link

The camera accepts control inputs through the Camera Link MDR26F connectors.

The camera ships in internal sync, internal programmed integration (exposure mode 2).

EXSYNC (Triggers Line Readout)

Line rate can be set internally using the serial interface. The external control signal EXSYNC is optional and enabled through the serial interface. This camera uses the **falling edge of EXSYNC** to trigger line readout. Section 3.2 Exposure Mode and Line Rate details how to set frame times, exposure times, and camera modes.

Output Signals, Camera Link

IMPORTANT:
This camera's data should be sampled on the rising edge of STROBE.

These signals indicate when data is valid, allowing you to clock the data from the camera to your acquisition system. These signals are part of the Camera Link configuration and you should refer to the Camera Link Implementation Road Map, available here, for the standard location of these signals.

Clocking Signal	Indicates
LVAL (high)	Outputting valid line
DVAL (high)	Valid data
STROBE (rising edge)	Valid data
FVAL (high)	Outputting valid frame

- The camera internally digitizes 12 bits and outputs 8 MSB or all 12 bits depending on the camera's Camera Link operating mode.

2.3 Camera Link Video Timing

Figure 4: Piranha 3 Overview Timing Showing Input and Output Relationships

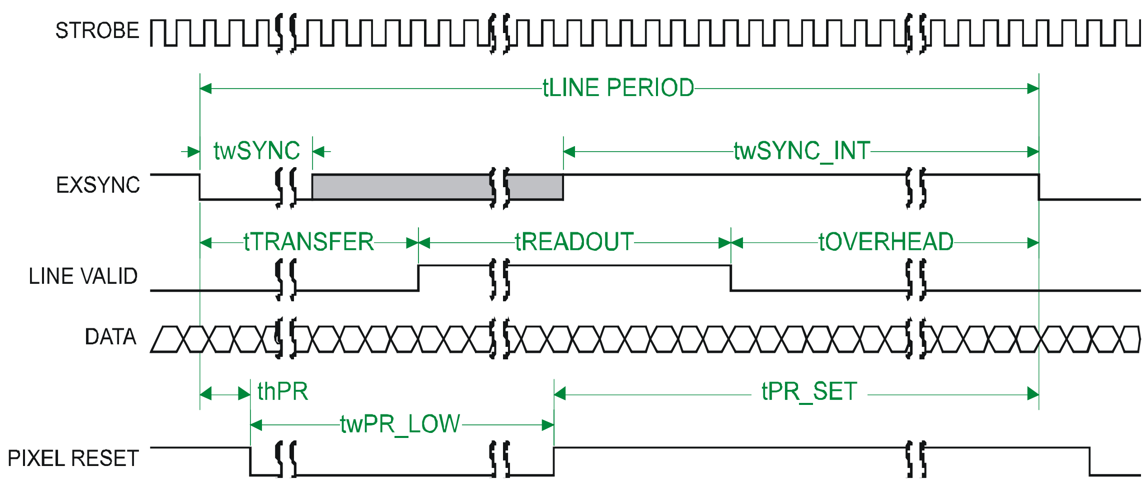


Figure 5: Piranha 3 Fixed (Programmed) Integration Timing with External EXSYNC

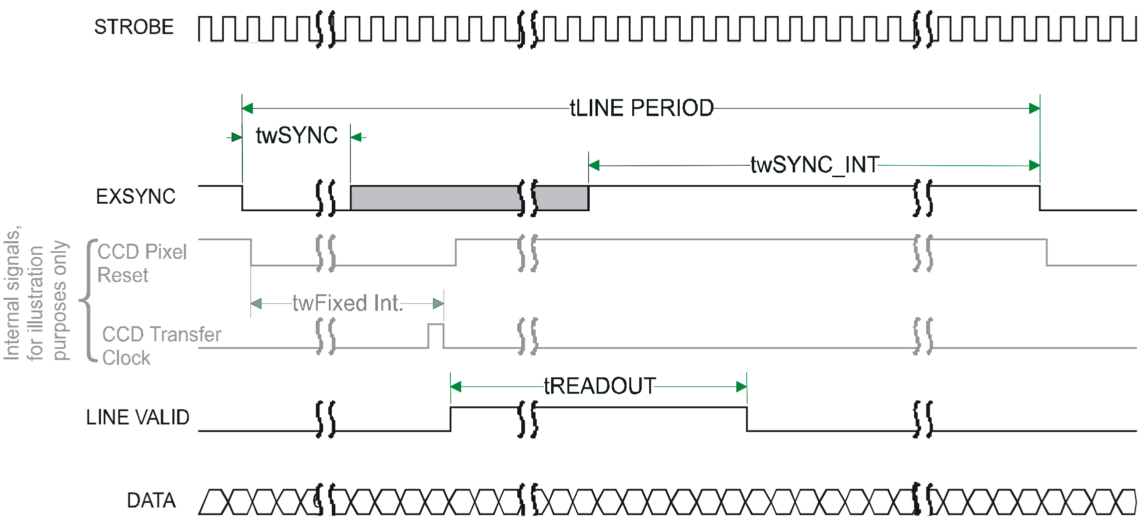


Table 11: Piranha 3 Input and Output

Symbol	Definition	Min (ns)
twSYNC	The minimum low width of the EXSYNC pulse when not in SMART EXSYNC mode.	100
$twSYNC_{(SMART)}$*	The minimum low width of the EXSYNC pulse when in SMART EXSYNC modes to guarantee the photosites are reset.	3,000
twSYNC_INT	The minimum width of the high pulse when the "SMART EXSYNC" feature is turned off	100
twSYNC_INT (SMART) *	Is the integration time when the "SMART EXSYNC" feature is available and turned on. Note that the minimum time is necessary to guarantee proper operation.	3,000

Symbol	Definition	Min (ns)
tLINE PERIOD (t_{LP})	The minimum and maximum line times made up of tTransfer, tREADOUT plus tOVERHEAD to meet specifications.	53,190 (12k) 106,382 (8k)
tTransfer	The time from the reception of the falling edge of EXSYNC to the rising edge of LVAL when pretrigger is set to zero. Pretrigger reduces the number of clocks to the rising edge of LVAL but doesn't change the time to the first valid pixel. If the fixed integration time mode of operation is available and selected then the integration time is added to the specified value.	3,725 ±25
twFixed Int.	Fixed Integration Time mode of operation for variable exsync frequency.	800
tREADOUT	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	38,400 (12k) 25,600 (8k)
tOVERHEAD	Is the number of pixels that must elapse after the falling edge of LVAL before the EXSYNC signal can be asserted. This time is used to clamp the internal analog electronics	425±25
thPR	Applies when the PRIN exposure control feature is enabled . The PRIN signal must be held a minimum time after the EXSYNC falling edge to avoid losing the integrated charge	Don't care
twPR_LOW	Minimum Low time to assure complete photosite reset	3,000
tPR_SET	The nominal time that the photo sites are integrating. Clock synchronization will lead to integration time jitter, which is shown in the specification as +/ - values. The user should command times greater than these to ensure proper charge transfer from the photosites. Failure to meet this requirement may result in blooming in the Horizontal Shift Register.	3,000

3

Software Interface: How to Control the Camera

All camera features can be controlled through the serial interface. The camera can also be used without the serial interface after it has been set up correctly. Functions available include:

- Controlling basic camera functions such as gain and sync signal source
- Flat field correction
- Generating a test pattern for debugging

The serial interface uses a simple ASCII-based protocol and the PC does not require any custom software.

Note: The command set may have changed from previous camera models. Do not assume that commands perform similarly to older cameras.

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 115,200 kbps baud rate
- Camera does not echo characters

This chapter outlines the more commonly used commands. See section A2 Commands for a list of all available commands.

Command Format

When entering commands, remember that:

- A carriage return <CR> ends each command.
- A space or multiple space characters separate parameters. Tabs or commas are invalid parameter separators.
- Upper and lowercase characters are accepted
- The backspace key is supported
- The camera will answer each command with either <CR><LF> OK > or <CR><LF> Error xx: Error Message > or Warning xx: Warning Message >. The > is used exclusively as the last character sent by the camera.

The following parameter conventions are used in the manual:

- **i** = integer value
- **f** = real number
- **m** = member of a set
- **s** = string
- **t** = tap id
- **x** = pixel column number
- **y** = pixel row number

Example: to return the current camera settings

gcp <CR>

Setting Baud Rate

Note on the camera and baud rate

The cameras employ a 115,200 fixed signal baud rate.

Camera Help Screen

For quick help, the camera can return all available commands and parameters through the serial interface.

There are two different help screens available. One lists all of the available commands to configure camera operation. The other help screen lists all of the commands available for retrieving camera parameters (these are called "get" commands).

To view the help screen listing all of the camera configuration commands, use the command:

Syntax:	**h**

To view a help screen listing all of the "get" commands, use the command:

Syntax:	**gh**
Notes:	For more information on the camera's "get" commands, refer to section Returning Camera Settings.

The camera configuration command help screen lists all commands available. Parameter ranges displayed are the extreme ranges available. Depending on the current camera operating conditions, you may not be able to obtain these values. If this occurs, values are clipped and the camera returns a warning message.

Some commands may not be available in your current operating mode. The help screen displays NA in this case.

3.1 First Power Up Camera Settings

When the camera is powered up for the first time, it operates using the following factory settings:

- Exposure mode 2
- 10 kHz line rate
- Factory gain + 10 dB
- Factory calibrated FPN and PRNU coefficients.

Note regarding start-up times: This camera requires approximately 20 seconds to power up.

3.2 Exposure Mode and Line Rate

How to Set Exposure Mode and Line Rate

You have a choice of operating the camera in one of four exposure modes. Depending on your mode of operation, the camera's line rate (synchronization) can be generated internally through the software command `ssf` or set externally with an EXSYNC signal (CC1).

To select how you want the camera's line rate to be generated:

1. You must first set the camera's exposure mode using the `sem` command.
2. Next, if using mode 2, use the command `ssf` to set the line rate. Refer to section Setting Frame Rate for details.

Setting the Exposure Mode

Purpose: Sets the camera's exposure mode allowing you to control your sync and line rate generation.

Syntax: **sem *m***

Syntax Elements: **m**

Exposure mode to use 2 / 3/ 4 / 6*. Factory setting is **2**.

Notes:

- Refer to Table 12: Exposure Modes for a quick list of available modes or to the following sections for a more detailed explanation including timing diagrams.
- To obtain the current value of the exposure mode, use the command `gcp` or `get sem`.
- When setting the camera to external signal modes, EXSYNC must be supplied.

Related Commands: `ssf`

Example: **sem 3**

Table 12: Exposure Modes

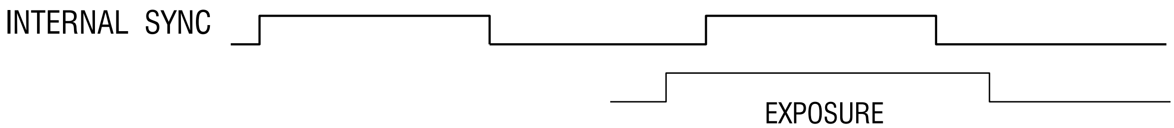
Mode	SYNC	Programmable Line Rate	Programmable Exposure Time	Description
2	Internal	Yes	Yes	
3	Internal	No	Yes	Maximum exposure time.
4	External	No	No	Exposure time equals EXSYNC high time.

Mode	SYNC	↓	↓	Description
*6	External	No	Yes	In this mode the line rate and the exposure time are mutually restrained by this formular: Maximum user line rate = 1 / ((1 / Max camera line rate) + exposure time) Assume the camera max line rate is 40 KHz in the following examples. Ex. 1) If the user wants the line rate is 25KHz, the max exposure time should be equal or smaller than 1/ 25KHz - 1/ 40KHz = 15 us; Ex. 2) If the user sets the exposure time to 25 us, the line rate should be equal or lower than 1/ (1/ 40KHz + 25us) = 20KHz.

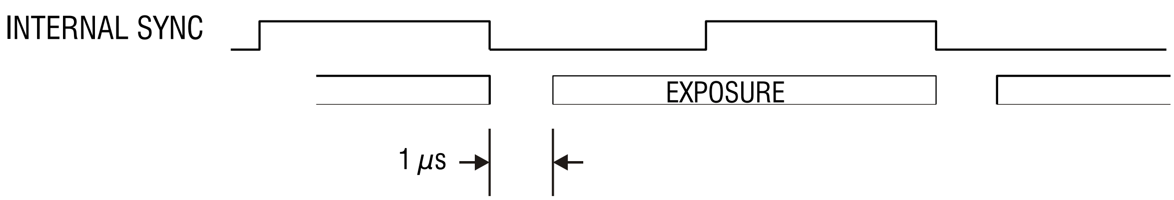
Exposure Modes in Detail

Figure 6: Timing Diagrams

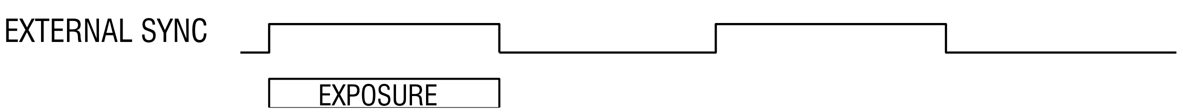
Mode 2: Internal SYNC, Programmable Line Rate and Exposure Time



Mode 3: Internal SYNC, Maximum Exposure Time



Mode 4: External SYNC



Mode 6: External SYNC, Programmable Exposure Time

Setting Frame Rate and Exposure Time

Setting the Frame Rate

Purpose:	Sets the camera's frame rate in Hz. Camera must be operating in exposure mode 2.
Syntax:	**ssf *f***
Syntax Elements:	***f*** Set the frame rate to a value from: 1 to 72070 (P3-S0-16k40 HSLink) or 1 to 40000 (P3-S0-16K20 HSLink and P3-80-16K40 Camera Link. Value rounded up/down as required.
Notes:	• If you enter an invalid frame rate frequency the value, the camera clips the frame rate to be within the current operating range and a warning message is returned. • If you enter a frame rate frequency out of the range displayed on the help screen, an error message is returned and the frame rate remains unchanged. • To return the camera's frame rate, use the commad **gcp** or **get ssf**.
Related Commands:	**sem**
Example:	**ssf 10000**

Setting the Exposure Time

Purpose:	Sets the exposure time in µs. The camera must be operating in mode 2, 3 or 8 to use this feature.
Syntax:	**set *f***
Syntax Elements:	***f*** The exposure time value in a range from: 1 to 8888 µs.
Notes:	• To read the current exposure time, use the gcp command. • If you enter an invalid exposure time, an error message is returned.
Related Commands:	**sem, ssf**
Example:	**set 400.5**

3.3 Data Processing

Digital Signal Processing Chain

Processing Chain Overview and Description

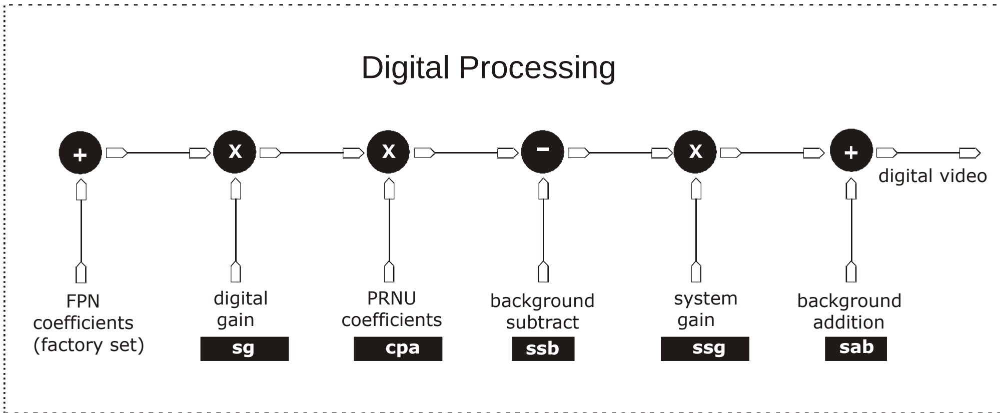
The following diagram shows a simplified block diagram of the camera's digital processing chain.

The digital processing chain contains the digital gain, FPN correction (factory set), the PRNU correction, the background subtract, and the system gain and offset. All of these elements are user programmable.

Notes:

- FPN and PRNU coefficients are stored separately. To save the current PRNU coefficients, use the command **wpc**.

Figure 7: Signal Processing Chain



Digital Processing

1. Fixed pattern noise (FPN) calibration (calculated at the factory) is used to subtract away individual pixel dark current.
2. Photo-Response Non-Uniformity (PRNU) coefficients are used to correct the difference in responsivity of individual pixels (i.e. given the same amount of light different pixels will charge up at different rates) and the change in light intensity across the image either because of the light source or due to optical aberrations (e.g. there many be more light in the center of the image). PRNU coefficients are multipliers and are defined to be of a value greater than or equal to 1. This ensures that all pixels will saturate together. When using PRNU correction, it is important that the A/ D offset and Fixed Pattern Noise (FPN) or per pixel offsets are subtracted prior to the multiplication by the PRNU coefficient. The subtraction of these 2 components ensure that the video supplied to the PRNU multiplier is nominally zero and zero multiplied by anything is still zero resulting in no PRNU coefficient induced FPN. If the offset is not subtracted from the video then there will be artifacts in the video at low light caused by the multiplication of the offset value by the PRNU coefficients.
3. Background subtract (**`ssb`** command), system gain (**`ssg`** command), and background addition (**`sab`**) are used to increase image contrast after FPN and PRNU calibration. It is useful for systems that process 8-bit data but want to take advantage of the camera's 12-bit digital processing chain. For example, if you find that your image is consistently between 128 and 255 DN (8-bit), you can subtract off 128 (**`ssb 2048`**) and then multiply by 2 (**`ssg 8192`**) to get an output range from 0 to 255.

Setting Gain

Use the set gain (sg) command to set the gain on taps 0 to 32 and in a range of ± 24 dB.

Command and parameter: `sg tf`, where `t` is tap 0 to 32 and `f` is ± 24 dB.

Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)

Flat Field Correction Overview

This camera has the ability to calculate correction coefficients in order to remove non-uniformity in the image. This video correction operates on a pixel-by-pixel basis and implements a two point correction for each pixel. This correction can reduce or eliminate image distortion caused by the following factors:

- Fixed Pattern Noise (FPN)
- Photo Response Non Uniformity (PRNU)

Lens and light source non-uniformity Correction is implemented such that for each pixel:

$$V_{output} = [(V_{input} - \text{dark offset} - FPN(\text{pixel})) * \text{digital gain} * PRNU(\text{pixel})]$$

where	V_{output}	=	digital output pixel value
	V_{input}	=	digital input pixel value from the CCD
	PRNU(pixel)	=	PRNU correction coefficient for this pixel
	FPN(pixel)	=	FPN correction coefficient for this pixel

The algorithm is performed in two steps. The fixed offset (FPN) is determined first by performing a calculation without any light. This calibration determines exactly how much offset to subtract per pixel in order to obtain flat output when the CCD is not exposed.

The white light calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

Flat Field Correction Restrictions

The FPN correction is done in the factory. Results of the FPN correction are used in the PRNU procedure. We recommend that you repeat the correction when a temperature change greater than 10°C occurs or if you change the integration time.

PRNU correction requires a clean, white reference. The quality of this reference is important for proper calibration. White paper is often not sufficient because the grain in the white paper will distort the correction. White plastic or white ceramic will lead to better balancing.

Note: If your illumination or white reference does not extend the full field of view of the camera, the camera will send a warning.

For best results, ensure that:

1. 60 Hz ambient light flicker is sufficiently low not to affect camera performance and calibration results.
2. The brightest pixel should be slightly below the target output.
3. When 6.25% (or more) of pixels from a single row within the region of interest are clipped, flat field correction results may be inaccurate.

Calibration Overview

When a camera images a uniformly lit field, ideally, all of the pixels will have the same gray value. However, in practice, this is rarely the case (see example below) as a number of factors can contribute to gray scale non-uniformity in an image: Lighting non-uniformities and lens distortion, PRNU (pixel response non-uniformity) in the imager, FPN (fixed pattern noise) in the imager, etc.

Figure 8. Image with non-uniformities

By calibrating the camera you can eliminate the small gain difference between pixels and compensate for light distortion. This calibration employs a two-point correction that is applied to the raw value of each pixel so that non-uniformities are flattened out. The response of each pixel will appear to be virtually identical to that of all the other pixels of the sensor for an equal amount of exposure.

Calibration Steps

Step 1: Preparing for Calibration

If you do not want to change the current camera settings, but want to calibrate the camera, skip this step and move to Step 2: PRNU Calibration.

To check the current camera settings, use the get camera parameters (gcp) or the get commands. You can change some or all of the following settings before calibrating:

- Set exposure mode using the command sem m, where m = 2/ 3/ 4/ / 6

  For example, `sem 2`

- Set line sync frequency (line rate) using the command ssf f, where f = - 72 kHz

  For example, `ssf 5000`

- Set exposure time using the command set f, where f = 1 - 8888 µs in an available mode.

  For example, `set 100`

- Set gain using command sg t i, where t are the taps 0 to 21 and i = ± 24 db

  For example, `sg t 0`

- Save user settings using command `wus`.

A Note on FPN or Dark Calibration

FPN calibration (also called dark calibration) is done in the factory.

Step 2: PRNU or White Calibration

1. Remove the lens cap and prepare a white, uniform target.

2. Adjust the line rate so that the average output is about 80% of the full output, or below the PRNU target value by:

   Adjusting the lighting, if you are using an internal exposure mode. Or,

   Adjusting the line rate, if you are using the Smart Exsync mode.

3. Calibrate the PRNU using the command **cpa 2 i,** where 2 is the PRNU calculated using the entered target value as shown in the formula on page 28 and i is the target value and the value of i is 1024 to 4055 DN.

   For example: cpa 2 3300

4. Save the PRNU coefficients using the command **wpc.**

   For example: wpc

Note: Both the FPN and PRNU coefficients are always turned on.

Digital Signal Processing for Processing

Updating the Gain Reference

To update the gain reference:

Purpose: Sets the current gain setting to be the 0 dB point. This is useful after tap gain matching to allow you to change the gain on all taps by the same amount.

Syntax: **`ugr`**

FPN Correction

Note: FPN correction is done in the factory.

PRNU Correction

Performing PRNU to a user entered value

Purpose: Performs PRNU calibration to user entered value and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light. Using this command, you must provide a calibration target.

Executing these algorithms causes the **`ssb`** command to be set to 0 (no background subtraction), the **`ssg`** command to 0 (unity digital gain), and the **`sab`** command to 0 (no background addition). The pixel coefficients are disabled during the algorithm execution but returned to the state they were prior to command execution.

Syntax: **`cpa m i`**

Syntax Elements: ***m***

PRNU calibration algorithm to use:

2 = Calculates the PRNU coefficients using the entered target value as shown below:

$$\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - \text{FPN}_i}$$

The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. Is is important that the target value (set with the next parameter) is set to be at least equal to the highest pixel across all cameras so that all pixels can reach the highest pixel value during calibration.

4 = Calculates the PRNU coefficient in the same way as **cpa 2** with the exception that this command only calculates PRNU for pixels within the current Region of Interest (ROI).

i

Peak target value in a range from 1024 to 4055 DN. The target value must be greater than the current peak output value.

Notes: The values for background subtract (ssb), system gain (ssg) and background add (sab) are set to 0, 1, and 0 respectively after using the cpa command.

Example: **`cpa 2 4000`**

Setting a Pixel's PRNU Coefficient

Purpose: Sets an individual pixel's PRNU coefficient.

Syntax: **`spc x i`**

Syntax Elements: ***x***

The pixel number from 1 to 16384.

i

Coefficient value in a range from 0 to 65535 where:

$$\text{prnu coefficient} = 1 + \frac{i}{4096}$$

Returning PRNU Coefficients

Purpose: Returns the current PRNU pixel coefficients for the range specified by ***x1*** and ***x2***.

Syntax: **`dpc x1 x2`**

Syntax Elements: ***x1***

Start pixel to display in a range from 1 to 16384.

x2

End pixel to display in a range from 1 to 16384.

Notes:

- If **x2**<**x1** then **x2** is forced to be **x1**.

Example: **`dpc 10 20`**

Subtracting Background

Purpose: Use the background subtract command after performing flat field correction if you want to improve your image in a low contrast scene. You should try to make your darkest pixel in the scene equal to zero.

Sytax **`ssb i`**

Syntax Elements: **i**

Subtracted value in a range in DN from 0 to 1024 (12 bit LSB).

Notes:

- See the following section for details on the **ssg** command.

Related Commands **ssg**

Example **`ssb 500`**

Setting System Gain

Purpose: Improves signal output swing after a background subtract. When subtracting a digital value from the digital video signal, using the **ssb** command, the output can no longer reach its maximum. Use this command to correct for this where:

$$\text{ssg value} = \frac{\text{max output value}}{\text{max output value - ssb value}}$$

Syntax: **`ssg i`**

Syntax Elements: **i**

Gain setting. The gain ranges are 0 to 61438. The digital video values are multiplied by this value where:

$$\text{System Gain} = 1 + \frac{i}{4096}$$

Notes:

- Use this command in conjunction with the **ssb** command (described above).

- We recommend that i is never set below 4096. Setting **i** to 0 will result in only 0 output data.
- Digital offset is set to zero after sending the command

Related Commands: **ssb, sab**

Example: **ssg 4500**

Adding Background

Purpse: Use the background add command after performing flat field correction if you want to improve your image in a high contrast scene. Use this command to increase the true black above 0 DN.

Sytax **sab i**

Syntax Elements: **i**

Add value in a range in DN from 0 to 4096 (12 bit LSB).

Notes:
- See the following section for details on the **ssg** command.

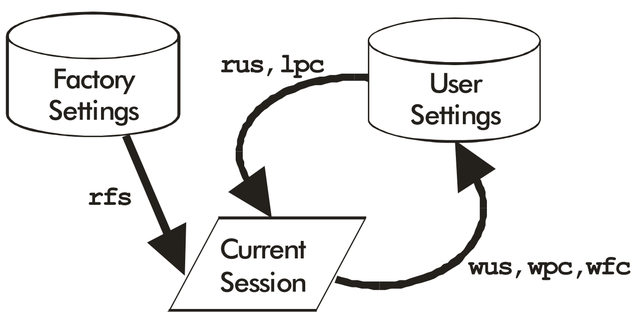
Related Commands **ssg, ssb**

Example **sab 500**

3.4 Saving and Restoring Settings

Saving and Restoring Factory and User Settings

Figure 9: Saving and Restoring Overview



Factory Settings

You can restore the original factory settings, including the factory calibrated pixel coefficient set, at any time using the command **rfs**.

User Settings

You can save or restore your user settings to non-volatile memory using the following commands.

- To save all current user settings to EEPROM for the current mode use the command **wus**. The camera will automatically restore the saved user settings when powered up.

  WARNING: While settings are being written to nonvolatile memory, do not power down camera or camera memory may be corrupted.

- To restore the last saved user settings, including the last used pixel coefficient set, for the current mode, use the command **rus**.

Current Session Settings

These are the current operating settings of your camera. These settings are stored in the camera's volatile memory and will not be restored once you power down your camera. To save these settings for reuse at power up, use the command **wus**.

Saving and Restoring PRNU and Coefficients

Selecting the Set Number

Purpose:	When saving and loading camera settings (e.g. PRNU coefficients), you have a choice of saving up to five different sets and loading from six different sets (five user and one factory). This command determines the set number from where these values are loaded and saved.
Syntax:	**ssn**
Syntax Elements:	**i** **0** = Factory set. Settings can only be loaded from this set. **1 - 5** = User sets. You can save, or load settings with these sets.
Note:	The camera powers up with the last set saved using this command.
Example:	**ssn 3**
Related:	**rus, wpc**

Saving the Current PRNU Coefficients

Purpose:	Saves the current PRNU coefficients for the current set.
Syntax:	**wpc**
Notes:	Use the ssn command first to select the set number to save to (1 – 5).

Loading a Saved Set of Coefficients

Purpose:	Loads a saved set of pixel coefficients. A factory calibrated set of coefficients is available.
Syntax:	**lpc**
Notes:	Use the ssn command first to select the set number to save to (1 – 5).

Rebooting the Camera

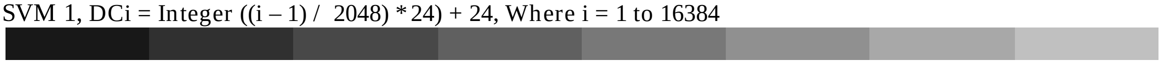
The command **rc** reboots the camera. The camera starts up with the last saved settings and the baud rate used before reboot. Previously saved pixel coefficients are also restored.

3.5 Diagnostics

Generating a Test Pattern

Purpose:	Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber.
Syntax:	**`svm i`**
Syntax Elements:	**`i`**
	`0` Video.
	`1 - 4` As shown below.

SVM 1, DCi = Integer ((i – 1) / 2048) * 24) + 24, Where i = 1 to 16384



SVM 2, HORi = Modulus (DCi + Modulus (Modulus ((i – 1), 2048), 256), 256), Where i = 1 to 16384

SVM 3, VERi = Modulus (DCi + (i – 1), 256), Where i = 1 to 256

SVM 4, DIAGi = Modulus ((HORi + VERi), 256), Where i = 1 to 16384

Figure 10. Test Image Patterns

Returning Video Information

The camera's microcontroller has the ability to read video data. This functionality can be used to verify camera operation and to perform basic testing without having to connect the camera to a frame grabber. This information is also used for collecting line statistics for calibrating the camera.

Returning a Single Line of Video

Purpose: Returns a complete line of video (without pixel coefficients or test pattern) displaying one pixel value after another. It also displays the minimum, maximum, and mean value of the line sampled within the region of interest.

Use the **gl** command, or the following **gla** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.

Syntax: **gl x1 x2**

Syntax Elements: ***x1***

Column start number. Must be less than the column end number in a range from **1** to 16384.

x2

Column end number. Must be greater than the column start number in a range from **2** to 16384.

Notes:

- If **x2** ≤ **x1** then **x2** is forced to be **x1**.
- Digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data.
- Values returned are in 12 bit DN.

Related Commands

Example: **gl 10 20**

Returning Averaged Lines of Video

Setting the Number of Lines to Sample

Purpose: Sets the number of lines to sample when using the **gla** command or for pixel coefficient calculations.

Syntax: **css m**

Syntax Elements: **m**

Number of lines to sample. Allowable values are **1024, 2048, or 4096**.

Notes:

- To return the current setting, use the **gcp** command.

Related Commands: **gla**

Example: **css 1024**

Returning the Average of Multiple Lines of Video

Purpose:	Returns the average for multiple lines of video data (without pixel coefficients or test pattern). The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics for the pixels in the region of interest.
Syntax:	**gla x1 x2**
Syntax Elements:	***x1*** Column start number. Must be less than the column end number in a range from **1** to **16383**. ***x2*** Column end number. Must be greater than the column start number in a range from **2** to **16384**.
Notes:	• If **x2** ≤ **x1** then **x2** is forced to be **x1**. • Digital offset, background subtract, and digital system gain are applied to the data. FPN and PRNU coefficients are not included in the data. • Values returned are in 12 bit DN.
Related Commands:	**css**
Example:	**gla 10 20**

Temperature Measurement

The internal temperature of the camera can be determined by using the **vt** command. This command will return the internal chip temperature in degrees Celsius. For proper operation, this value should not exceed 75 °C.

Note: If the camera's internal temperature reaches 75 °C, the camera **will shutdown and the LED will flash red**. If this occurs, the camera **must be rebooted** using the command, **rc** or can be powered down manually. You will have to correct the temperature problem or the camera will shutdown again.

IMPORTANT! Refer to the camera mounting instructions below for more information on managing the camera temperature.

Voltage Measurement

The command **vv** displays the camera's input voltage. Note that the voltage measurement feature of the camera provides only approximate results (typically within 1%). The measurement should not be used to set the applied voltage to the camera but only used as a test to isolate gross problems with the supply voltage.

Camera Frequency Measurement

Purpose:	Returns the EXSYNC frequency (CC1).
Syntax:	**gsf**
Example:	**gsf**

Returning Camera Settings

Returning All Camera Settings with the Camera Parameter Screen

The camera parameter (GCP) screen returns all of the camera's current settings.

To read all current camera settings, use the command:

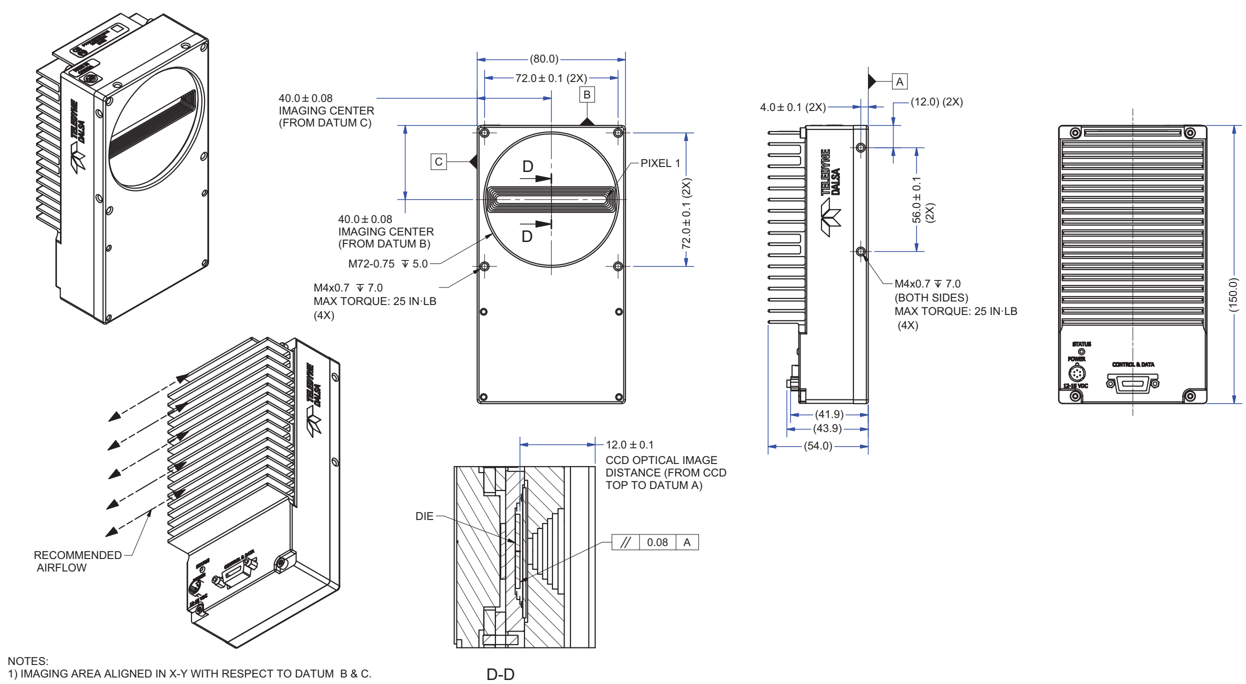
Syntax: **`gcp`**

Returning Camera Settings with Get Commands

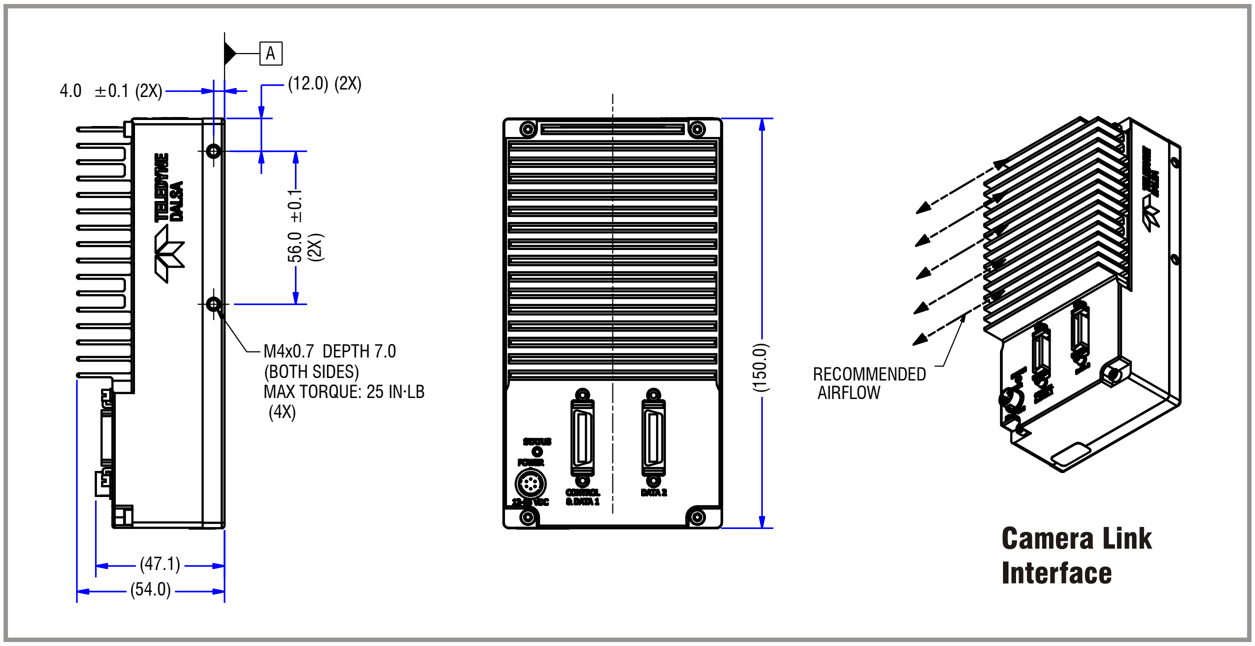
You can also return individual camera settings by inserting a "**`get`**" in front of the command that you want to query. If the command has a tap or pixel number parameter, you must also insert the tap number or pixel number that you want to query. Refer to the Command section later in this manual for a list of available commands. To view a help screen listing the following get commands, use the command **`gh`**.

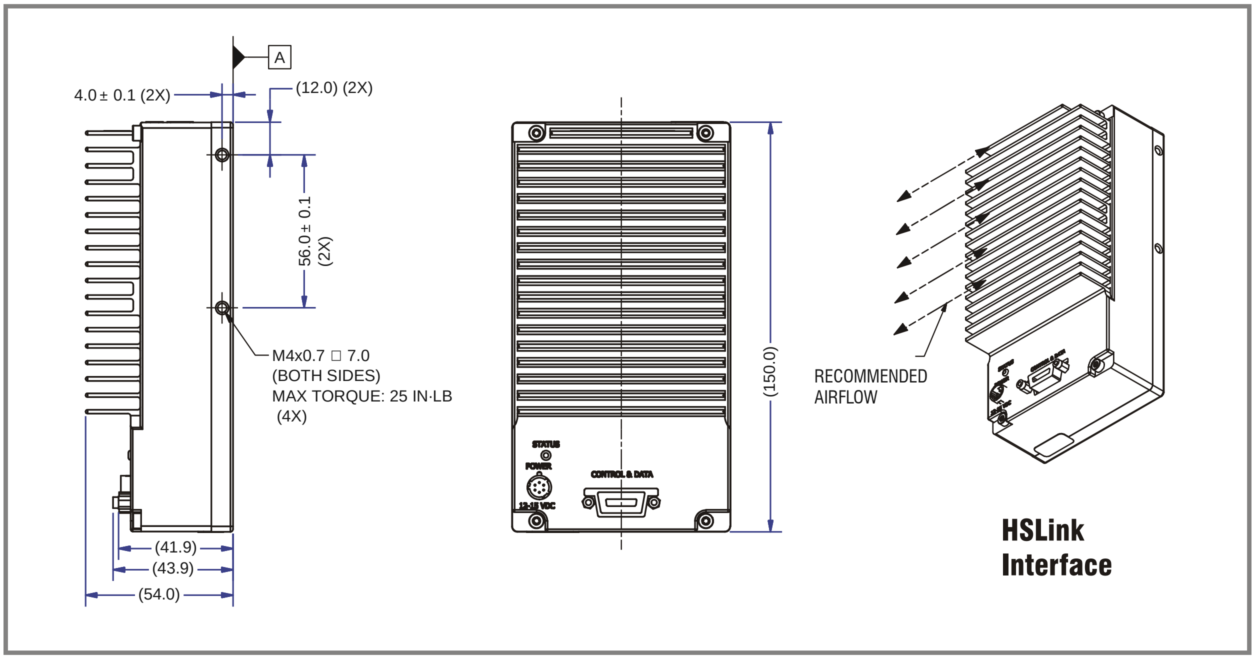
4

Optical and Mechanical



NOTES:
1) IMAGING AREA ALIGNED IN X-Y WITH RESPECT TO DATUM B & C.
2) ROTATION OF THE CCD IMAGING AREA IS ± 0.6°.
3) LENS MOUNT POSITION WITH RESPECT TO IMAGING AREA: X-Y ± 0.175 MM.


A
4.0 ±0.1 (2X)
(12.0) (2X)
56.0 ±0.1 (2X)
M4x0.7 DEPTH 7.0
(BOTH SIDES)
MAX TORQUE: 25 IN·LB
(4X)
(47.1)
(54.0)
(150.0)
RECOMMENDED
AIRFLOW
Camera Link
Interface


A
4.0± 0.1 (2X)
(12.0) (2X)
56.0± 0.1 (2X)
M4x0.7 □ 7.0
(BOTH SIDES)
MAX TORQUE: 25 IN·LB
(4X)
(41.9)
(43.9)
(54.0)
(150.0)
RECOMMENDED
AIRFLOW
HSLink
Interface

4.1 Lens Mounts

Model Number	Lens Mount Options
All models	M72x0.75 thread.

4.2 High Temperature and Mounting

Warning! Depending on the mounting design and the operating conditions the camera body could become hot. You must take precautions to ensure your safety and avoid touching the camera directly during operation.

Mounting Instructions and Recommendations

Proper camera mounting ensures that the heat generated by the camera dissipates properly and that the camera maintains a safe temperature.

1. The camera should be bolted tightly to a mounting plate made of thermally conductive material (e.g. Aluminum).
2. Keep contact area between the camera's front surface and the mounting plate surface as large as possible. Do not use "stand-off" style mounting.
3. Design the camera mounting plate so that there is enough surface area to dissipate heat.
4. Forced air flow to the fins is the most effective way to cool the camera. If forced air flow is not available, then leave enough space around the fins so that heat can easily dissipate into the air by natural convection.
5. The mount setup plus the airflow must dissipate 40 Watts or more of heat.
6. Proper thermal mounting of the camera should result in an internal camera temperature < 65 ºC (verify using command vt) and a front plate temperature < 50 ºC.

Note: To avoid internal damage the camera automatically shuts down when the internal temperature reaches 75 ºC.

The recommendations assume the following conditions:

- The camera mounting plate is equal to the full camera mounting surface (as shown) and maximum natural convection surface.
- No impediments to the natural convection space around the surface of the mounting plate and the surface of the camera.
- An environment temperature of approximately 25 ºC.
- Good contact between the mounting plate and the camera surface.

5

Troubleshooting

5.1 Common Solutions

The information in this chapter can help you solve problems that may occur during the setup of your camera. Remember that the camera is part of the entire acquisition system. You may have to troubleshoot any or all of the following:

- power supplies
- frame grabber hardware & software
- light sources
- operating environment
- cabling
- host computer
- optics
- encoder

LED

When the camera is first powered up, the LED will glow on the back of the camera. Refer to section LED Status Indicator for information on the LED.

Connections

The first step in troubleshooting is to verify that your camera has all the correct connections.

Power Supply Voltages

Check for the presence of all voltages at the camera power connector. Verify that all grounds are connected. Issue the command, **vv**, to confirm correct voltages.

EXSYNC

When the camera is received from the factory, it defaults (no external input required) to exposure mode 2 (10 kHz line rate, internal Sync to trigger readout). After a user has saved settings, the camera powers up with the saved settings.

Data Clocking/Output Signals

To validate cable integrity, have the camera send out a test pattern and verify it is being properly received. Refer to section Generating a Test Pattern for further information.

5.2 Troubleshooting Using the Serial Interface

The following commands can aid in debugging. (The complete command protocol is described in Appendix B and C.)

Communications

To quickly verify serial communications send the help command. The **h** command returns the online help menu. If further problems persist, review Appendix C for more information on communications.

Verify Parameters

To verify the camera parameters, send the **gcp** command.

Verify Factory Calibrated Settings

To restore the camera's factory settings and disable the FPN and PRNU coefficients, send the **rfs** command.

After executing this command send the **gcp** command to verify the factory settings.

Verify Timing and Digital Video Path

Use the test pattern feature to verify the proper timing and connections between the camera and the frame grabber and verify the proper output along the digital processing chain. See below.

Generating Test Patterns

The camera can generate a test pattern to aid in system debugging. Use the command **svm 1** to activate the test pattern. The test pattern is a ramp from 0 to 255DN, then starts at 0 again. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber.

- **No test pattern or bad test pattern**— May indicate a problem with the camera (e.g. missing bit) or a system setup problem (e.g. frame grabber or timing). Verify the presence of the LVAL and STROBE signals.
- **Test pattern successful**— Run the **svm 0** command to activate video. Then run the **gl** command under both dark and light conditions to retrieve a line of raw video (no digital processing).

Verify Voltage

To check the camera's input voltage, use the **vv** command. If it is within the proper range, the camera returns OK> and the voltage value. Otherwise the camera returns an error message.

Verify Temperature

To check the internal temperature of the camera, use the **vt** command. For proper operation, this value should not exceed 75°C.

Note: If the camera reaches 75°C, the camera **will shutdown and the LED will flash red**. If this occurs, the camera **must be rebooted** using the command, **rc** or can be powered down manually. You will have to correct the temperature problem or the camera will shutdown again. If you enter any command other than **vt** or **rc**, the camera responds with:

Error 09: The camera's temperature exceeds the specified operating range>

Verify Pixel Coefficients

Use the **dpc** command to display the PRNU pixel coefficients.

5.3 Specific Solutions

No Output or Erratic Behavior

If your camera provides no output or behaves erratically, it may be picking up random noise from long cables acting as antennae. Do not attach wires to unused pins. Verify that the camera is not receiving spurious inputs (e.g. EXSYNC if camera is in exposure mode that requires external signals). Unused signals in the cable should be termintated in 100Ω.

Line Dropout, Bright Lines, or Incorrect Frame Rate

Verify that the frequency of the internal sync is set correctly, or when the camera is set to external sync that the EXSYNC signal supplied to the camera does not exceed the camera's useable frame rate under the current operating conditions.

Noisy Output

Check your power supply voltage outputs for noise. Noise present on these lines can result in poor video quality.

Dark Patches

If dark patches appear in your output the optics path may have become contaminated. Clean your lenses and sensor windows with extreme care.

1. Take standard ESD precautions.
2. Wear latex gloves or finger cots
3. Blow off dust using a filtered blow bottle or dry, filtered compressed air.
4. Fold a piece of optical lens cleaning tissue (approx. 3" x 5") to make a square pad that is approximately one finger-width
5. Moisten the pad on one edge with 2-3 drops of clean solvent—either alcohol or acetone. Do not saturate the entire pad with solvent.

Appendix A

Error Handling and Command List

A1 Error Handling

The following table lists warning and error messages and provides a description and possible cause. Warning messages are returned when the camera cannot meet the full value of the request; error messages are returned when the camera is unable to complete the request.

Table 13: Warning and Error Messages

Warning Messages	
Camera Response	**Comment**
OK>	Camera executed command
Warning 01: Outside of specification>	Parameter accepted was outside of specified operating range (e.g. gain greater than ±10 dB of factory setting, or SSF below specification).
Warning 02: Clipped to min>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 03: Clipped to max>	Parameter was clipped to the current operating range. Use GCP or GET to see value used.
Warning 04: Related parameters adjusted>	Internal operating condition is adjusted to accommodate the entered command. E.g. requesting exposure time longer than line time automatically adjusts the line time to meet the exposure time requirement.
Warning 07: Coefficient may be inaccurate A/D clipping has occurred>	In the region of interest (ROI) greater than 6.251% single or 1% of averaged pixel values were zero or saturated.
Warning 08: Greater than 1% of coefficients have been clipped	Greater than 1% of FPN or PRNU coefficients have been calculated to be greater than the maximum allowable and so were clipped.
Warning 09: Internal line rate inconsistent with read out time>	Changing this parameter has changed read out time and that is greater than the *internal* SYNC

Error Messages	
Camera Response	**Comment**
Error 01: Internal error xx>	Where xx is a code list below. Only output during power up. Customer should contact customer support.
Error 02: Unrecognized command>	Command is not valid.
Error 03: Incorrect number of parameters>	Too many or too few parameters.
Error 04: Incorrect parameter value>	This response returned for

Error Messages	
	▪ Alpha received for numeric or vise-versa ▪ Float where integer expected ▪ Not an element of the set of possible values. E.g., Baud Rate ▪ Outside the range limit
Error 05: Command unavailable in this mode>	E.g. SSF when in SEM 3
Error 06: Timeout>	Command not completed in time. E.g. CCP in SEM 3 when no external EXSYNC is present.
Error 07: Camera settings not saved>	Indicates that user settings have been corrupted by turning off the power while executing the WUS command. Must build up new settings from factory and re-save with WUS.
Error 08: Unable to calibrate - tap outside ROI>	Cannot calibrate a tap that is not part of the end of line statistics.
Error 09: The camera's temperature exceeds the specified operating range>	Indicates that the camera has shut itself down to prevent damage from further overheating. (flashing red) Shuts down at internal temperature of 75˚C and will not restart until below 65˚C (equivalent to 50˚C at front plate).
Error 10: FPGA Flash Program Failed	FCS failed either because of communication error or a bad file was sent.

A2 Commands: Quick Reference

As a quick reference, the following table lists all of the camera configuration commands available to the camera user. For detailed information on using these commands, refer to Chapter 3. Note: This table does not list "get" commands. Refer to section Returning Camera Settings for a list of these commands.

Parameters:
`t` = tap id
`i` = integer value
`f` = float
`m` = member of a set
`s` = string
`x` = pixel column number
`y` = pixel row number

Table 14: Command Quick Reference

Mnemonic	Syntax	Parameters	Description
calculate PRNU algorithm	cpa	m i	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where m is: 2 = Calculates the PRNU coefficients using the entered target value as shown below: $\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - \text{FPN}_i}$ The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. 4 = This algorithm is the same as 2 with the exception that it only calculates PRNU for the pixels within the current Region of Interest (ROI). The second parameter is the target value to use in a range from 1024 to 4055 DN. The values for background subtract (ssb), system gain (ssg) and background add (sab) are set to 0, 1, and 0 respectively after using the cpa command.
correction set sample	css	m	Set number of line samples averaged for pixel coefficient calculations or for output of **gla** command. Values: 1024, 2048, 4096. Refer to Returning Averaged Lines of Video on page 33 for details.
display pixel coeffs	dpc	x1 x2	Displays the PRNU pixel coefficients. x1 = Pixel start number x 2= Pixel end number In a range from 1 to 16384.
get command log	gcl		
get camera model	gcm		Reads the camera model number.
get camera parameters	gcp		Reads all of the camera parameters.
get camera serial	gcs		Read the camera serial number.
get camera version	gcv		Read the firmware version and FPGA version.
get values	get		
get help	gh		Returns a help screen listing all of the “get” commands.
get line	gl	x x	Gets a line of raw video (no digital processing or test pattern) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line. x = Pixel start number x = Pixel end number In a range from 1 to 16384. Refer to Returning a Single Line of Video on page 33 for details.

Mnemonic	Syntax	Parameters	Description
get line average	gla	x x	Read the average of line samples. x = Pixel start number x = Pixel end number in a range from 1 to 16384. Refer to Returning Averaged Lines of Video on page 33 for details.
get prnu coeff	gpc	x	Read the PRNU coefficient. x = pixel number to read in a range from 1 to 16384 count.
get signal frequency	gsf		Returns the EXSYNC frequency.
help	h		Display the online help. Refer to section for details.
help, single command	?	s	
load fpn coefficients	lfc		Loads the factory set fpn coefficients from non-volatile memory.
load pixel coefficients	lpc		Loads the previously saved pixel coefficients from non-volatile memory.
read bit error counter	rbc		
reset camera	rc		Reset the entire camera (reboot). Baud rate is not reset and reboots with the value last used.
restore factory coefficients	rfc	i	0: load PRNU coefficients from factory set 1: load PRNU coefficients from one of user sets. The user set selected is dependent on the current selection made using the ssn command.
restore factory settings	rfs		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0. Refer to section 3.4 Saving and Restoring Settings for details.
reset stats counter	rsc		
restore user settings	rus		Restore the camera's last saved user settings and FPN and PRNU coefficients. Refer to section 3.4 Saving and Restoring Settings for details.
set add background	sab	i	0 - 4096
set binning horizontal	sbh	m	1: no binning, every single pixel is the independent output unit. 2: every adjacent odd and even two pixels are bound together become a single output unit, therefore, the sensor size becomes ½ of its maximum size.
set data width	sdw	i	8 10, or 12 bit operation.
set exposure mode	sem	m	Set the exposure mode: 2 = Internal SYNC, programmable line rate and exposure time. 3 = Internal SYNC, maximum exposure time 4 = External SYNC 6 = External SYNC, programmable exposure time.
Set exposure time	set	f	Sets the exposure time in a range of 1 to 8888 µs.
set gain	sg	t f	t = 0-32 f = ± 24 dB

Mnemonic	Syntax	Parameters	Description
set hslink mode	shm	i	0 – 6 (HSLink model only).
set prnu coeff	spc	x i	Set the PRNU coefficient. x=pixel number within the range 1 to 16384. i= PRNU value within the range 0 to 65535
set prnu range	spr	x1 x2 i	Sets the PRNU range. x1 = 1 to 16384 x2 = 1 to 16384 i = 0 to 65535
set subtract background	ssb	i	Subtract the input value from the output signal. i = Subtracted value in a range from 0 to 1024
set sync frequency	ssf	f	Set the frame rate to a value from: -1 to 72070 (P3-S0-16k40 HSLink) -1 to 40000 (P3-S0-16K20 HSLink and P3-80-16K40 Camera Link) Value rounded up/ down as required. Refer to Setting Frame Rate on page 24 for details.
set system gain	ssg	i	Set the digital gain. i = Digital gain in a range from 0 to 61438. The digital video values are multiplied by this number. Refer to Setting System Gain on page 29 for details.
set set number	ssn	i	0 – 5. 0 = factory settings. 1 – 5 = user sets.
set video mode	svm	i	Switch between normal video mode and test patterns: svm 0 to 4 Refer to section Generating a Test Pattern for details.
update gain reference	ugr		Changes 0 dB gain to equal the current gain value.
verify temperature	vt		Check the internal temperature of the camera
verify voltage	vv		Check the camera's input voltages and return OK or fail
write PRNU coeffs	wpc	i	Write all current PRNU coefficients to EEROM. Refer to section Saving and Restoring PRNU and Coefficients for details.
write user settings	wus		Write all of the user settings to EEROM. Refer to section Saving and Restoring Factory and User Settings for details.

Appendix B

Camera Link Map

Note: The **sdw** command sets the data width to either 8, 10, or 12 bit depths.

The following tables show show the assignment of pixel data bits to the input pins on the X, Y and Z Camera Link transmitters the camera. They also show the assignments for the corresponding output pins on the X, Y and Z Camera Link receivers in a frame grabber.

The assignments for the frame valid bit and the line valid bit are also listed.

Transmitter X				
Port	Camera	Frame Grabber	Signal	
			8 Tap 8 Bit	8 Tap 10 Bit
Port A0	TxIN0	RxOUT0	D0 Bit 0	D0 Bit 2
Port A1	TxIN1	RxOUT1	D0 Bit 1	D0 Bit 3
Port A2	TxIN2	RxOUT2	D0 Bit 2	D0 Bit 4
Port A3	TxIN3	RxOUT3	D0 Bit 3	D0 Bit 5
Port A4	TxIN4	RxOUT4	D0 Bit 4	D0 Bit 6
Port A5	TxIN6	RxOUT6	D0 Bit 5	D0 Bit 7
Port A6	TxIN27	RxOUT27	D0 Bit 6	D0 Bit 8
Port A7	TxIN5	RxOUT5	D0 Bit 7 (MSB)	D0 Bit 9 (MSB)
Port B0	TxIN7	RxOUT7	D1 Bit 0	D1 Bit 2
Port B1	TxIN8	RxOUT8	D1 Bit 1	D1 Bit 3
Port B2	TxIN9	RxOUT9	D1 Bit 2	D1 Bit 4
Port B3	TxIN12	RxOUT12	D1 Bit 3	D1 Bit 5
Port B4	TxIN13	RxOUT13	D1 Bit 4	D1 Bit 6
Port B5	TxIN14	RxOUT14	D1 Bit 5	D1 Bit 7
Port B6	TxIN10	RxOUT10	D1 Bit 6	D1 Bit 8
Port B7	TxIN11	RxOUT11	D1 Bit 7 (MSB)	D1 Bit 9 (MSB)
Port C0	TxIN15	RxOUT15	D2 Bit 0	D2 Bit 2
Port C1	TxIN18	RxOUT18	D2 Bit 1	D2 Bit 3
Port C2	TxIN19	RxOUT19	D2 Bit 2	D2 Bit 4
Port C3	TxIN20	RxOUT20	D2 Bit 3	D2 Bit 5
Port C4	TxIN21	RxOUT21	D2 Bit 4	D2 Bit 6
Port C5	TxIN22	RxOUT22	D2 Bit 5	D2 Bit 7
Port C6	TxIN16	RxOUT16	D2 Bit 6	D2 Bit 8
Port C7	TxIN17	RxOUT17	D2 Bit 7 (MSB)	D2 Bit 9 (MSB)
LVAL	TxIN24	RxOUT24	Line Valid	Line Valid
FVAL	TxIN25	RxOUT25	Frame Valid	Frame Valid
DVAL or Port I0 *	TxIN26	RxOUT26	Not Used	-
			-	D0 Bit 0
Port I1	TxIN23	RxOUT23	Not Used	D0 Bit 1
Strobe	TxINCLK	RxOUTCLK	Pixel Clock	Pixel Clock

* In 8 tap 8 bit mode, this port is DVAL and is not used. In 8 tap 10 bit mode, this port is Port I0 and D0 Bit 0 is assigned to it.

Transmitter Y				
Port	Camera	Frame Grabber	Signal	
			8 Tap 8 Bit	8 Tap 10 Bit
Port D0	TxIN0	RxOUT0	D3 Bit 0	D3 Bit 2
Port D1	TxIN1	RxOUT1	D3 Bit 1	D3 Bit 3
Port D2	TxIN2	RxOUT2	D3 Bit 2	D3 Bit 4
Port D3	TxIN3	RxOUT3	D3 Bit 3	D3 Bit 5
Port D4	TxIN4	RxOUT4	D3 Bit 4	D3 Bit 6
Port D5	TxIN6	RxOUT6	D3 Bit 5	D3 Bit 7
Port D6	TxIN27	RxOUT27	D3 Bit 6	D3 Bit 8
Port D7	TxIN5	RxOUT5	D3 Bit 7 (MSB)	D3 Bit 9 (MSB)
Port E0	TxIN7	RxOUT7	D4 Bit 0	D4 Bit 2
Port E1	TxIN8	RxOUT8	D4 Bit 1	D4 Bit 3
Port E2	TxIN9	RxOUT9	D4 Bit 2	D4 Bit 4
Port E3	TxIN12	RxOUT12	D4 Bit 3	D4 Bit 5
Port E4	TxIN13	RxOUT13	D4 Bit 4	D4 Bit 6
Port E5	TxIN14	RxOUT14	D4 Bit 5	D4 Bit 7
Port E6	TxIN10	RxOUT10	D4 Bit 6	D4 Bit 8
Port E7	TxIN11	RxOUT11	D4 Bit 7 (MSB)	D4 Bit 9 (MSB)
Port F0	TxIN15	RxOUT15	D5 Bit 0	D5 Bit 2
Port F1	TxIN18	RxOUT18	D5 Bit 1	D5 Bit 3
Port F2	TxIN19	RxOUT19	D5 Bit 2	D5 Bit 4
Port F3	TxIN20	RxOUT20	D5 Bit 3	D5 Bit 5
Port F4	TxIN21	RxOUT21	D5 Bit 4	D5 Bit 6
Port F5	TxIN22	RxOUT22	D5 Bit 5	D5 Bit 7
Port F6	TxIN16	RxOUT16	D5 Bit 6	D5 Bit 8
Port F7	TxIN17	RxOUT17	D5 Bit 7 (MSB)	D5 Bit 9 (MSB)
LVAL	TxIN24	RxOUT24	Line Valid	Line Valid
FVAL or Port I2 *	TxIN25	RxOUT25	Frame Valid	-
			-	D1 Bit 0
DVAL or Port I3 **	TxIN26	RxOUT26	Not Used	-
			-	D1 Bit 1
Port I4	TxIN23	RxOUT23	Not Used	D2 Bit 0
Strobe	TxINCLK	RxOUTCLK	Pixel Clock	Pixel Clock

* In 8 tap 8 bit mode, this port is FVAL and the frame valid signal is assigned to it. In 8 tap 10 bit mode, this port is Port I2 and D1 Bit 0 is assigned to it.

** In 8 tap 8 bit mode, this port is DVAL and is not used. In 8 tap 10 bit mode, this port is Port I3 and D1 Bit 1 is assigned to it.

Transmitter Z				
Port	Camera	Frame Grabber	Signal	
			8 Tap 8 Bit	8 Tap 10 Bit
Port G0	TxIN0	RxOUT0	D6 Bit 0	D6 Bit 2
Port G1	TxIN1	RxOUT1	D6 Bit 1	D6 Bit 3
Port G2	TxIN2	RxOUT2	D6 Bit 2	D6 Bit 4
Port G3	TxIN3	RxOUT3	D6 Bit 3	D6 Bit 5
Port G4	TxIN4	RxOUT4	D6 Bit 4	D6 Bit 6
Port G5	TxIN6	RxOUT6	D6 Bit 5	D6 Bit 7
Port G6	TxIN27	RxOUT27	D6 Bit 6	D6 Bit 8
Port G7	TxIN5	RxOUT5	D6 Bit 7 (MSB)	D6 Bit 9 (MSB)
Port H0	TxIN7	RxOUT7	D7 Bit 0	D7 Bit 2
Port H1	TxIN8	RxOUT8	D7 Bit 1	D7 Bit 3
Port H2	TxIN9	RxOUT9	D7 Bit 2	D7 Bit 4
Port H3	TxIN12	RxOUT12	D7 Bit 3	D7 Bit 5
Port H4	TxIN13	RxOUT13	D7 Bit 4	D7 Bit 6
Port H5	TxIN14	RxOUT14	D7 Bit 5	D7 Bit 7
Port H6	TxIN10	RxOUT10	D7 Bit 6	D7 Bit 8
Port H7	TxIN11	RxOUT11	D7 Bit 7 (MSB)	D7 Bit 9 (MSB)
Port I5	TxIN15	RxOUT15	Not Used	D2 Bit 1
Port I6	TxIN18	RxOUT18	Not Used	D3 Bit 0
Port I7	TxIN19	RxOUT19	Not Used	D3 Bit 1
Port K0	TxIN20	RxOUT20	Not Used	D4 Bit 0
Port K1	TxIN21	RxOUT21	Not Used	D4 Bit 1
Port K2	TxIN22	RxOUT22	Not Used	D5 Bit 0
Port K3	TxIN16	RxOUT16	Not Used	D5 Bit 1
Port K4	TxIN17	RxOUT17	Not Used	D6 Bit 0
LVAL	TxIN24	RxOUT24	Line Valid	Line Valid
FVAL or Port K5 *	TxIN25	RxOUT25	Frame Valid	-
			-	D6 Bit 1
DVAL or Port K6 **	TxIN26	RxOUT26	Not Used	-
			-	D7 Bit 0
Port K7	TxIN23	RxOUT23	Not Used	D7 Bit 1
Strobe	TxINCLK	RxOUTCLK	Pixel Clock	Pixel Clock

* In 8 tap 8 bit mode, this port is FVAL and the frame valid signal is assigned to it. In 8 tap 10 bit mode, this port is Port K5 and D6 Bit 1 is assigned to it.

** In 8 tap 8 bit mode, this port is DVAL and is not used. In 8 tap 10 bit mode, this port is Port K6 and D7 Bit 0 is assigned to it.

Appendix C

EMC Declaration

We, **Teledyne DALSA**
605 McMurray Rd.,
Waterloo, ON
CANADA N2V 2E9

declare under sole responsibility, that the product(s):

P3-x0-16Kx0-00-R

fulfill(s) the requirements of the standards outlined below which satisfy the EMC requirements for CE marking, the FCC Part 15 requirements, and the Industry Canada ICES-003 evaluation.

Radiated emissions requirements:

EN 55022 (2006)
EN 55011 (2009)
ICES-003
CISPR 22 (1993)
CISPR 11
FCC Part 15

Immunity to disturbances:

EN55024 (1998)
EN 61326-1 (2006)

Place of Issue	Waterloo, ON, CANADA
Date of Issue	March 10, 2011
Name and Signature of authorized person	**Hank Helmond** **Quality Manager, Teledyne DALSA Corp.**

Appendix D

Revision History

Revision	Change Description	Date
00	Preliminary release.	February 27, 2012
01	Revised camera mechanical. Imaging center measured at 40.0 ±0.08 mm, not ±0.05 as previously stated.	October 9, 2013
02	X and Y alignment tolerance value in the specifications table changed from ± 50 µm to ± 80 µm to match the mechanical drawing. Revised mechanical drawing added showing the correct tolerance.	December 4, 2013

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